ON TAKING BEARINGS

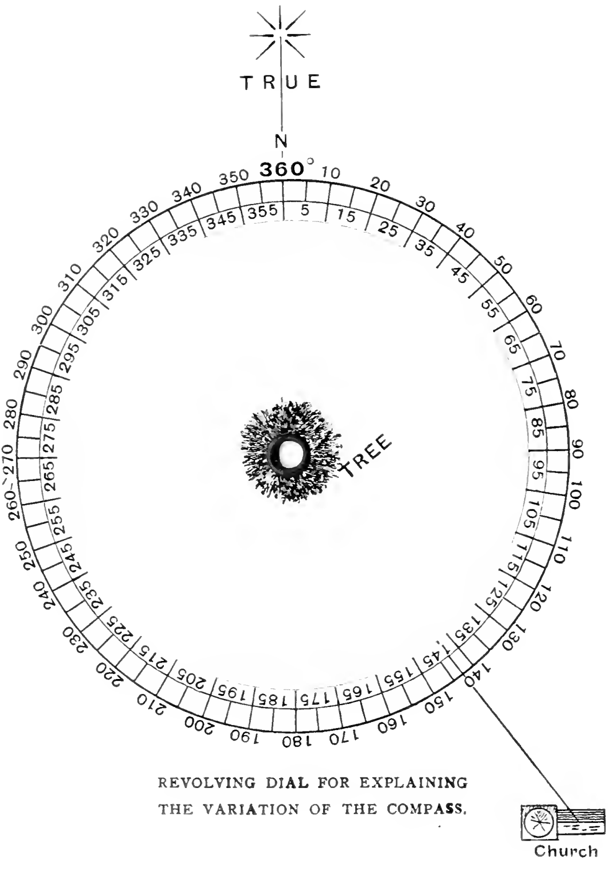
A SIMPLE TREATISE ON BEARINGS, WHAT THEY ARE AND HOW TO USE THEM FROM A MILITARY STANDPOINT

BY H. P. WALSH

CAPT. 3RD LOYAL NORTH LANCASHIRE REGIMENT

1/- NET

LONDON
JOHN MURRAY, ALBEMARLE STREET, W.
1916



REVOLVING DIAL FOR EXPLAINING
THE VARIATION OF THE COMPASS.

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PREFACE

It is the sincere hope of the author that this work may prove of some help to those who, especially at this period, are in hurried training for the Army. To many, much that is in it will seem redundant, to others there may be points which are not clear; but the writing of it is the outcome of lecturing to those whose normal occupations in life are far removed from the apparent intricacies of bearings and their uses, and who, at first, find some difficulty in them. For the same reason the Appendix on "Scales of Yards" has been added.

H. P. W.

FELIXSTOWE.
August 1915.

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ON TAKING BEARINGS

CHAPTER I

BEARINGS

"True bearing is the angle a line makes with the true north line."—*Manual of Map Reading and Field Sketching*, 1912.

DRAW a circle and divide it into four equal parts and name the points where the two diameters cut the circle as the cardinal points of the compass, thus:

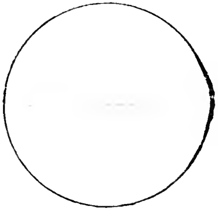


FIG. 1.

Now divide the circumference of the circle into 360 equal parts, commencing from the north point; then, commencing from the division next on the right

to the north point, number each division. Thus from 1 you work round as if following the hands of a clock, and this will bring you to the following points: East will be 90, South will be 180, West will be 270, and North will be 360. Each of these divisions is called a degree.

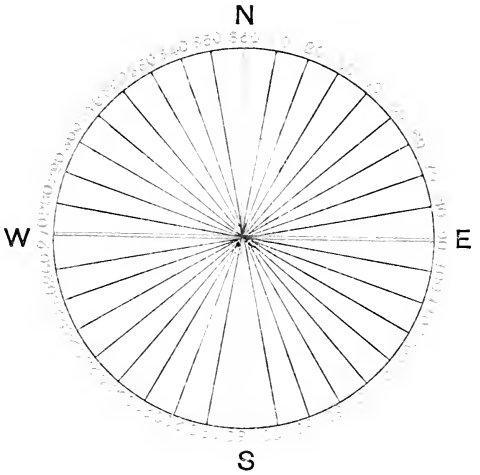


FIG. 2.—FOR THE PURPOSES OF THE DIAGRAM ONLY EVERY TENTH DIVISION IS SHOWN.

The next thing you have to do is to grasp clearly the idea of the angles upon which the system of bearings is worked. For instance, an angle of 90 degrees (written

90°) is the angle between the north line and the east line (see Fig. 3).

The angle between the north line and the south line, which of course are in the same straight line, is an angle of 180° (see Fig. 4).

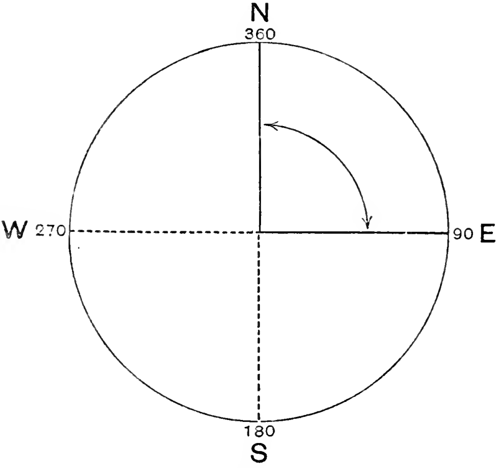


FIG. 3.

From this point the angles go on increasing by following the direction of the hands of a clock. The angle made by the west line and the north line is an angle of 270° (see Fig. 5).

So you will see that a straight line may be drawn from the centre of the circle to any one of the divisions round the circumference, and will thus give the angle

made with the north line. Note the four examples on page 6.

This is very simple, and the student, having mastered it, will now be able to apply his knowledge as follows:

Let it be supposed that you wish to find the bearing

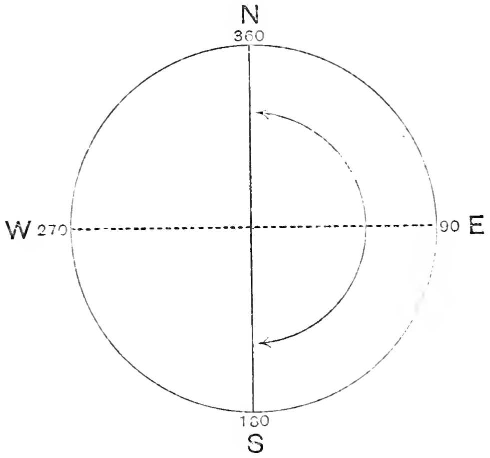


FIG. 4

from one object to another in the country. We will say that you are standing beneath a tree, and in the near distance you can see a church. You wish to find the *bearing from the tree to the church.* Please note that this is not in the least the method by which you *would* or *could* find the bearing, but is the theory of

what exactly happens when bearings are taken, and what they are.

Imagine that you know the direction of the north exactly. Now, using the centre of the trunk of the tree as a pivot, describe a circle of any size you like

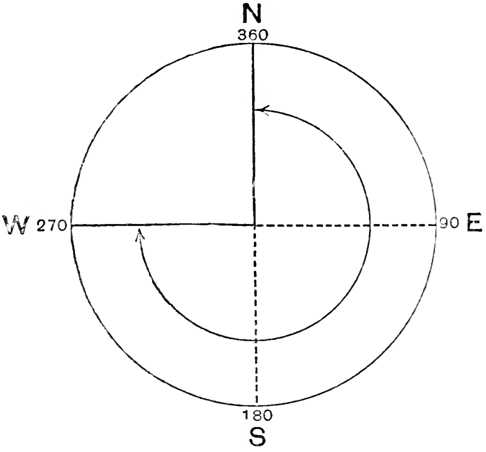


FIG. 5.

round the tree, on the ground. From the centre of the circle draw a straight line in the direction of the north out to the circumference of the circle. Divide this circle up into 360° as already described, then from the centre of the circle again draw a straight line on the ground out to the most central point of the church on the ground. This line must cut your circle at or

near one of the 360 equal divisions. In diagram I it will cut the circle at the 143rd division, therefore the bearing from the tree to the church is 143°, or the angle

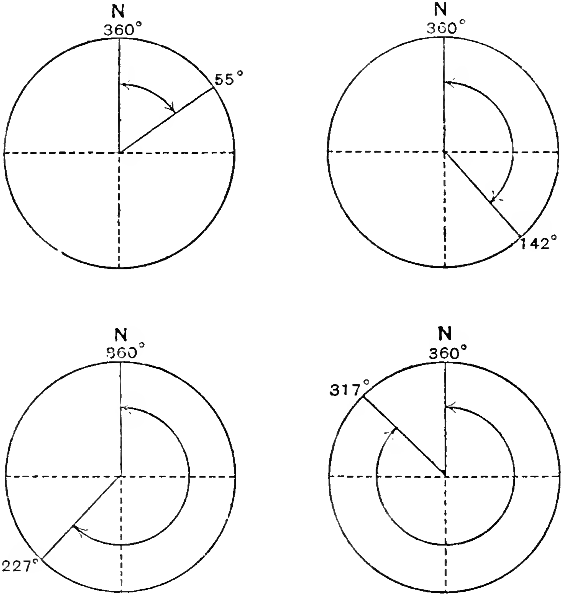


FIG. 6.

made by a line drawn from the tree to the church and a line drawn true north is 143°. Supposing the line from t e tree to the church had cut your circle half-way

between the 143rd and the 144th division, the bearing would have been $143\frac{1}{2}°$.

DIAGRAM I.

Now let us take the other case. Suppose that you are standing at the church and you want to know the *bearing from the church to the tree.* Proceed in exactly the same way, using the centre of the church as the centre of your circle.

DIAGRAM II.

You will find that the bearing from the church to the tree is 323°.

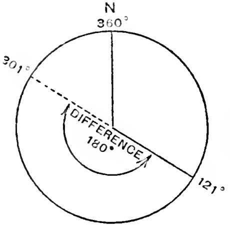
This brings us to BACK-BEARINGS.

Suppose you are at the tree and that it is impossible for you to get to the church and you want to know the bearing from the *church to the tree*, the full theoretical

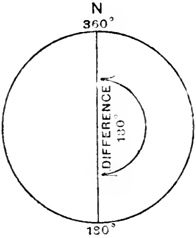
FIG. 7.

procedure is as follows. Find firstly the bearing from the tree to the church. You find it to be 143°; a bird's-

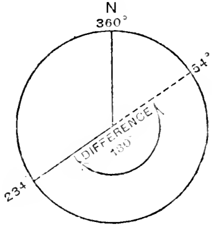
FIG 8.



Bearing 121°, less than 180° therefore add 180°. Back-bearing 301°.



Bearing 180°, add <u>or</u> subtract 180° back-bearing 0° or 360° which are the same.



Bearing 234°, greater than 180° therefore subtract 180° back-bearing 54°.

FIG. 9.

eye view of your tree and church with the circle and lines drawn would look as in Fig. 7. Now continue the line drawn from the tree to the church in the direction *away from* the church until it cuts the circle on the side furthest from the church (see Fig. 8), and you will find that it will cut your circle at the 323rd division. This is the BACK-BEARING—which is the same as the bearing *from the church to the tree*. You will now see that since the bearing and the back-bearing are in the same straight line there must be 180 of your divisions of the circumference of the circle between them, as there are between the north and the south; therefore the difference between a bearing and its back-bearing is always 180°. So that if your bearing is *less* than 180°, and you want to find the back-bearing, you *add* 180, and if it is more than 180° you subtract 180. The three diagrams on page 9 should make this quite clear.

This completes all that there is to know of the theory of bearings. We will go into the practical methods of using them when the student has mastered the compass and protractor, which are dealt with fully in the next chapter.

CHAPTER II

PART I—THE PROTRACTOR

THE military protractor is one of the most useful instruments with which the officer has to deal; one cannot say that it is more or less important than the compass, the one being dependent upon the other. The protractor should always be carried, preferably in the pocket of the Field Message Book, which will do much to prevent its being chipped or broken.

The chief use of the protractor is to enable one to find the bearing of one place from another *on a map* without the drawing of the circle described in Chapter I, and also to draw any angle that may be required on paper for the purposes of calculation. Remember always in using a protractor to have as fine a point to your pencil as possible, and to draw the finest possible lines. Besides this ensuring the greatest accuracy, if working on a map, the map is more easily cleaned afterwards.

Diagram III (see page 13) explains the protractor as far as it is concerned with bearings. (You will see by this time that the size of the circle used for getting bearings is immaterial as long as the north line is in the right direction and the centre of the circle exactly on the spot from which you wish to take the bearing: see next page.)

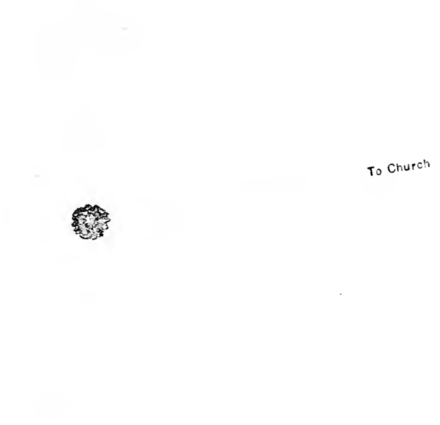


FIG. 10.

Now let us look at Diagram III. You will see drawn a circle, such as we described round the tree and the church, and you now know that if we make a circle, say of cardboard, and carry it with us and are able to place it upon any spot from which we wish to take a bearing, we can always use it, provided that it is properly divided up and we always point the north line to the north. A protractor is a handy, portable, and adapted form of this circle.

Now look at the red portion of Diagram III (A). This represents a protractor. Take the centre of the left-hand side of the protractor and from this point describe a circle, the diameter of which is formed by the whole left side of the protractor. Then divide

CONSTRUCTION OF A PROTRACTOR

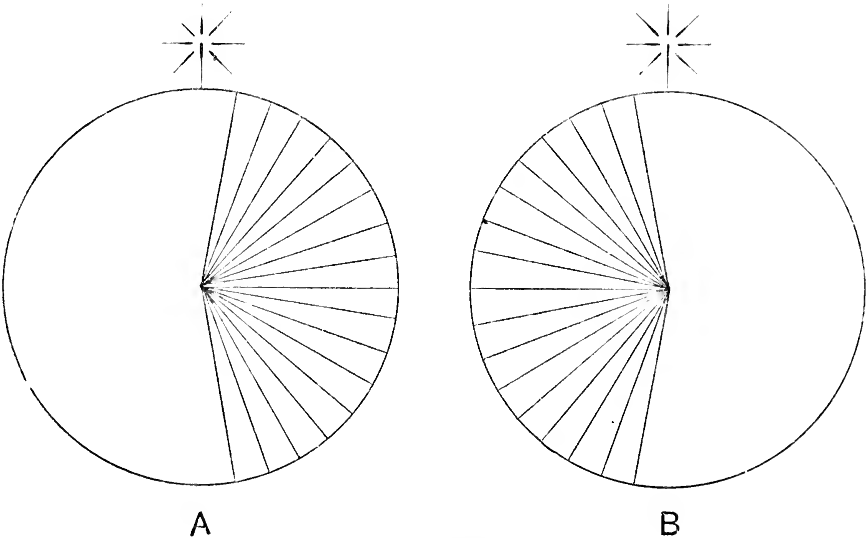


DIAGRAM III

the *right-hand* side of the circle up into 180 equal parts, making the lines cut the edge of the protractor. Mark the point in the centre of the left side of the protractor as the centre of the circle. Now you will be able on any map to get any bearing up to 180° between any two points you like to choose.

Suppose that you have a map upon which your tree and your church are marked and you want to find the *bearing from the tree to the church*, you will proceed as follows. First of all draw a line from the tree pointing to the north, that is, parallel to the north line which is marked on the map. Then join up the church and the tree by a straight line, using a pencil with a fine point and working carefully.

FIG. 11.

Now place the centre of the circle, that is the centre of the left-hand side of the protractor, upon the tree, and align the north line of the circle, that is the left side of the protractor from the centre to the top, with the north line that you have already drawn on the map—you will find then that the line joining the tree

to the church cuts the edge of your protractor at the 143rd division. Therefore the bearing from the tree to the church you find to be 143°. You will now see that by using the protractor thus you can find any bearing on a map from any spot to any other spot *eastwards* of it, that is, any bearing up to 180°. Note that if the two points are near enough to each other

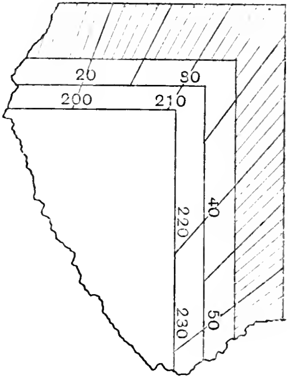


FIG. 12.

to be entirely hidden by the protractor when it is placed in position on the map, it is only necessary to produce the line which joins them until it is long enough to protrude beyond the edge of the protractor.

Now look at the red portion of Diagram III (B). Suppose that you are still using the same circle which you described for Diagram III (A), but that instead of working with the right-hand side of the circle, you

use the left. Imagine that you stick a pin through the centre of the circle where point of the red arrow-head is on the protractor, and that you then swivel the protractor round from right to left until it covers the left side of the circle. You then divide the left side of the circle up into 180 equal parts, and you number them from 181 to 360, as already described, and mark off where the lines cut the edge of the pro-

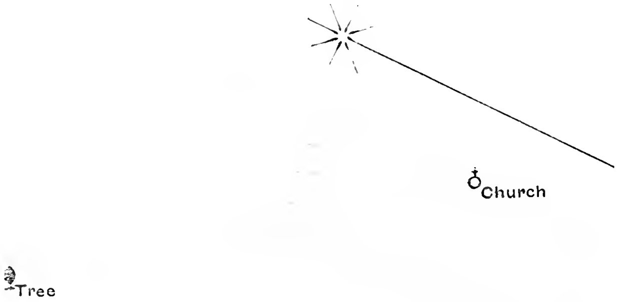


FIG. 13.

tractor. You will, of course, find that these division lines come exactly in the same places as those which you made with the protractor on the right-hand side of the circle, so that all you have to do is to number each line twice, once for when you are using the protractor on the right-hand side of the circle, and once for when you are using the left-hand side, that is eastwards or westwards.

Each of these degrees is the *back-bearing* of the other; thus, in the above diagram, 200 is the back-bearing of

20, and 20 is the back-bearing of 200. This will be quite clear to you by referring to the section on "back-bearings" in combination with Diagram III. (You will notice that on the protractor the tens only are marked, to save a superabundance of figures.) Now that you have the bearings from 180° to 360° on your protractor you will be able, on the map, to take the bearing from the church to the tree by drawing a north line from the church and joining up the church and the tree, taking care to use the protractor pointing the right way, as the line which before formed the north line (on the left-hand side of the protractor) will now form the *south* line on the right as the whole is, as it were, swivelled round on the pin.

Another use for a protractor is to plot a bearing or bearings from any given spot on a map. For instance, you are told that there is a sniper in a tree bearing 59° from a certain church. You look at your map and see many trees marked thereabout, so you have to plot the bearing on the map to find the correct one. Draw a line due north from the centre of the church. Place the protractor on the line, taking care to align the north line with the north line which you have just drawn on the map, and to have the centre of the protractor on the centre of the church as already described. Now at the point where the 59th division cuts the edge of the protractor, make a point with your pencil on the map. Then join up the church and the point you have just made, and produce this straight line until it cuts one of the trees, as, if your information is correct, it will do. This will be the tree which is at a bearing of 59° from the church.

As a finish to this part of the chapter it will be a good exercise for the student to discover which of the

trees in Diagram IV is at a bearing of 59° from the church, by plotting the bearing as just described actually on the page of the book as on a map. Use a finely-

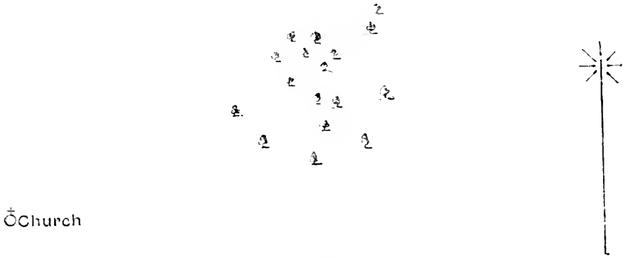


DIAGRAM IV

pointed pencil and work carefully. The solution will be found among the answers at the back of the book.

Note.—This is merely an exercise. Single trees are not marked with such accuracy on small-scale maps.

CHAPTER II—*Continued*

PART II—THE PRISMATIC COMPASS

By this time the student will have fully mastered the theory of bearings and their practical application on paper. The next thing to do is to learn how the bearings of different objects are taken actually on the ground. To enable the doing of this, a thorough understanding of the compass is necessary. The compass, reduced to its lowest terms, is simply the portable and adaptable form of the circle described in Chapter I for use on the ground, as the protractor is the form used for map and paper work. The chief difference is that the protractor has to be so placed as to point the north line to the north on the paper, while the compass, being made with a magnetic needle, is allowed to swing freely on a pivot, and thus points the north line to the north automatically on the ground.

The prismatic compass is a combination of a prism and a dial which enables a person taking a bearing to read the bearing on the dial, and, at the same time, to keep the eye on the object to which he is taking the bearing.

Look at the dial of an ordinary compass and you will see that it is simply a reproduction of the circle with which you are now familiar, divided up into 360 degrees and with the north point clearly marked by an arrow-head.

This dial is so balanced on a pivot as to revolve freely and easily, and is mounted on a magnetic needle, so that when the dial is set gently swinging it comes to rest with the arrow-head pointing to the north, thus making the divisions which mark the degrees

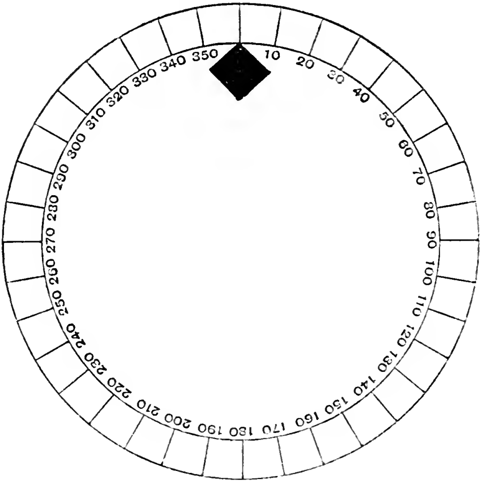


FIG. 14.

radiate outwards in the right directions as regards the north.

Now imagine that you are in possession of a perfect compass dial—perfectly balanced, and which, when brought to rest, has its arrow-head pointing exactly to

the north, and that you take it out with you to the tree from which the church is visible in the near distance, and proceed to take the bearing from the tree to the church. You will notice first of all that you are unable to place your dial so that the centre of it comes exactly over the centre of the tree. This does not matter: as long as you stand close to the tree on an imaginary straight line joining the tree and the church, the bearing will be the same. It does not matter about standing close to the tree as long as you *are* on the straight line. The following diagram will make this clear, but it is easier to get on the line the closer you are to the tree.

FIG. 15.

Imagine now that you stick the needle upon which your dial is pivoted into the ground on the straight line from the tree to the church, keeping as close to the tree as possible. The dial will swing gently, and, since we imagined a perfect compass-dial, will come to rest with the arrow-head pointing to the north. You then look at it and see that the 143rd division is pointing exactly to the centre of the church—therefore you know the bearing from the tree to the church to be 143°.

This is what actually happens when you take a bear-

ing with your prismatic compass—though of course there are adjuncts to the compass to make the task accurate and easy. You can now take the bearing *from the church to the tree* by going over to the church and proceeding in the same way.

In actually using the prismatic compass you put up the lid at right-angles to the dial, look through the narrow slot, cover the centre of church with the hair line on the glass, and you will see (presupposing the perfect compass again) what is given in the next diagram.

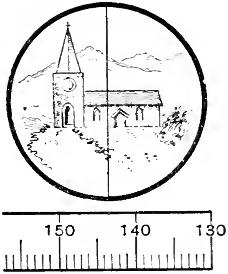


FIG. 16.

For reasons which we need not enter into here, the effect of the prism is to make the numbers read from right to left. This is provided for by a special dial, and it is only necessary that the student should be aware of the fact when reading the degrees between the tens and the fives, so that he does not count the wrong way.

We will now suppose that the student decides to take his own prismatic compass out to the tree, and

to take the bearing of the church from the tree. Beforehand he has used his protractor on a map, and has found the bearing to be 143°. He goes to the tree, leans his back against it, holds the compass to his eye, allows the dial to come to rest, and this is what he sees:

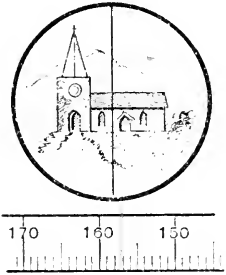


FIG. 17.

The bearing which he knows to be 143°, *having carefully worked it out on a map, is given by his compass as* 158°. Why?

Because the arrow-head of the compass is not pointing exactly to the true north; that is, although the centre of the circle represented by the compass dial is on the straight line from the tree to the church, the north line which is drawn from the centre of the circle on the dial is not exactly parallel to the north line which we originally imagined as being drawn from the centre of the trunk of the tree out to the circumference of the circle. This, you will see by looking at the diagram on the next page, must affect the bearing as registered by the compass dial.

FIG. 18.

(The chief point to remember in studying the above diagram is that each red circle is to be considered as a compass dial, with the degrees marked on it, and able to turn on its pivot.)

Now turn to the revolving dial which you will find inside the cover of this book and once more bring your imagination into play. You will see your tree and church clearly marked. Imagine the black circle to be the circle which we drew round the tree on the ground in the first chapter. The north line of the circle points to the north, and the line joining the tree and the church cuts the black circle at the 143rd degree. You know that your compass gave you a bearing of 158°, so imagine the red revolving portion to be your compass dial, and swivel it round until the 158th division cuts the straight line from the tree to the church. This is how your compass dial is placed when you read the bearing. What about the arrow-head which ought to be pointing to the north? You find it to be pointing westwards of the north. How many degrees westwards? Since the true bearing is 143°, and the bearing given by the compass, called the "magnetic bearing," is 158°, the difference is 15°. You know that your arrow-head has gone to the west—therefore the

error of your compass, called the variation, is known as "15° WEST."

A bearing which is taken from the line pointing true north is called a "true" bearing. A bearing which is taken from a line following the direction in which the magnetic needle is pointing, is called a "magnetic bearing." In all military orders and messages *true* bearings must be, and are, given. Magnetic bearings are useless unless the recipient of the order or message knows the variation of the magnetic north line upon which they are based.

Having learnt this, work out the following problem. You take a true bearing from the map, and find it to be 235°. You then take a magnetic bearing on the ground, and find it to be 245°. What is the variation of your compass? (Answer given, problem 2.)

Supposing, again, that you have taken the bearing of the church from the tree, and the compass dial reads 128°. Proceed as follows: Turn the dial on the chart round until the 128th division covers the line from the tree to the church. You will see that the arrow-head has now moved to the *east* of north. The difference between the bearings is 15°. Therefore the variation of your compass is 15° EAST.

It is only in speaking of the variation of a compass that the words EAST *and* WEST *are used in conjunction with degrees.* You will see that a *bearing* of 15° WEST is simply called 345°.

Knowing a true bearing to be 65°, you take it with a prismatic compass and find it to be 45°. What is the variation of the compass? (Problem 3.)

It will be noticed that when the *true* bearing is greater than the *magnetic* bearing, the *variation* of the compass is EAST, and when the *true* bearing is *less* than the

magnetic the variation is WEST, the amount of variation being the difference in degrees between the two bearings.

There is an exception to this rule, and that is *when the difference between the two bearings is more than* 180°.

For instance, work out the following on the revolving dial. You find a true bearing to be 75°, and a magnetic bearing to be 275°. Plot this with the dial and you will find that the arrow-head is to the EAST of north, although the magnetic bearing is greater than the true. The reason of this is quite clear in that you cannot have a variation WEST of more than 180°, because immediately the arrow-head leaving the true northwestwards crosses the 180th division of the black circle it gets into the east side of the circle, and, as degrees of variation are counted, starting from the north, *outwards*, the variation in the present case is 160° EAST, the 160° being the difference between the bearings subtracted from 360, the number of divisions in the circle.

Such a case as the above is extreme and not likely to occur, but the following is quite likely, and belongs to a class of questions set in examination papers. True bearing 5°, magnetic bearing 350°, find the variation of the compass. (Problem 4.)

True bearing 340°, magnetic bearing 5°, find the variation of the compass. (Problem 5.)

So you can now lay down definitely the following rule:

If the true is greater than the magnetic, EAST; *if the magnetic is greater than the true,* WEST; *the amount of variation being the difference in degrees between the two bearings; provided that the difference is not greater than* 180°. *If the difference is greater than* 180° *the*

above rule is reversed, the amount of variation being the difference between the bearings subtracted from 360.

Therefore to find the variation of your compass take your map and find two points on it that are clearly marked and are visible from each other on the ground. Read the true bearing with your protractor on the map, and then take the bearing on the ground with the compass. The difference of the bearings will give you the variation.

The reason that the arrow-head on the compass-dial does not point exactly to the north is that the force which attracts the needle is not at the north pole, nor is it in a straight line between the needle and the pole. There is no real necessity for the student, for present purposes, to go more fully into this; suffice it for him to realise that, at different places on the earth's surface, the arrow-head on the dial will point closer to or further from the true north, sometimes to the east of it and sometimes to the west; that in some places the true and the magnetic north will coincide; and that the difference between the true north and the magnetic north is not the same from year to year at the same spot.

The reason that different compasses may have different variations at the same time and place, is due to very slight and unavoidable flaws in manufacture and to wear and tear

Thus the student will see the necessity of continually checking the variation of his own compass, which, owing to the change in the variation due to natural laws and to the wear and tear of constant use, may alter as much as half a degree, or even more, in a year.

The variation in England at present (1915) is about 15° WEST.

Remember that your compass is affected by iron, so never take bearings in the vicinity of iron, and if out with your men and you need to take a bearing, get at least 50 yards away so that the effect of the rifles may be annulled.

CHAPTER III

Resection and Intersection

"Resection: A method by which the sketcher determines his position by observing the bearings of, and drawing lines from, at least two previously fixed points."—*Manual of Map Reading and Field Sketching*, 1912.

By this time the student will be thoroughly familiar with the taking of bearings. This chapter is devoted to the use of bearings in practice for (*a*) finding one's own position on a map, and (*b*) determining the exact position and range of distant objects. It is a most excellent exercise to make excursions into the surrounding country with a map, protractor, field-message book, and prismatic compass, and carry out resection and intersection with prominent objects on the ground.

Let us take resection, using again our tree and church. In all these examples the variation of the compass used is taken as 15° west.

Suppose that you are in the country and you want to indicate the exact position of yourself on the map. The first thing to do is to look round and find two prominent objects (more if they are available), and then find them marked on the map. You will then know roughly where you are—but you would not be able to put the point of a pin upon the exact spot. In the distance you are able to recognise a tree and a

church, and you see that they are also marked on the map. With your compass take the bearing on to the tree. You find it to be 10°. Take your message book and make a note: "Tree 10° magnetic." Then you take the bearing of the church and find it to be 90°. Make another note: "Church 90° magnetic."

Now since you have taken the bearings on the same spot, all you have to do is to plot the bearing-lines on the map, and the point where the lines cut must be the spot where you are. Proceed as follows: Take your map, and from the tree and the church draw north lines *parallel with the true north marked on the map.* Then

FIG. 19.

refer to the notes that you have made of the bearings and you find, "Tree 10° magnetic." Now you are working on the map with the true north, so you must convert the bearing from a magnetic one into a true one. You know that the variation of your compass is 15° west, and you can now find the true bearing by applying the following rule.

If you know the variation of the compass and wish to convert a magnetic bearing into a true one, if the variation is *west* you *subtract* the number of degrees of

variation from the magnetic bearing, and this will give the true bearing. If the variation is *east*, you *add* the number of degrees of variation to the magnetic bearing, and this will give you the true bearing.

In the present case, then, you subtract: 15 from 10 is minus 5, which on the dial of true bearings (the black one inside the cover) is 355°. If you apply this to the revolving dial by shifting the red arrow-head 15° to the west of north, it will be quite clear. Therefore if the magnetic bearing is 10°, the true bearing is 355°. This is the bearing from you to the tree, but since you do not know where you are you cannot plot it, but you can easily plot the *back-bearing* from the tree by reversing your protractor, and this will come to the same thing. The back-bearing of 355° is 175°, so plot a bearing of 175° from the tree (see Fig. 20).

Fig. 20

You then know that your position on the *map* is *somewhere* on this line.

The next thing is to refer to your notes, and you find "Church 90° magnetic." This gives you a true

bearing of 75°. The back-bearing of 75° is 255°, so from the church plot a bearing of 255° (see Fig. 21).

FIG. 21.

You then know that you must be somewhere on the bearing-line from the church, and since you know that you are also on the bearing-line from the tree, the spot where you are on the map must be where these lines cut. You can now put a pin point on your position on the map. Use a hard pencil with a very fine point, mark lightly, and rub out the lines when you have finished.

If you can see a third point to which you can take a bearing so much the better, for this will test the accuracy of your working.

Resection can also be done sometimes with only one point to which to take a bearing. This is when you are on a definitely defined line such as a road, a railway, or a river. Imagine yourself to be walking along the

road marked in the following plan, and you suddenly wish to fix your exact position on the road.

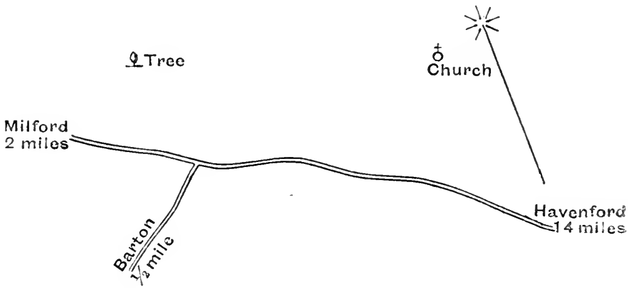


FIG. 22.

You take the bearing to the church and find it to be 73° magnetic. Draw your true north line from the church. You find your true bearing to be 58°. Plot the back-bearing of 58° (238°) from the church, and where this line cuts the road is the spot where you are, since you know yourself to be on the road and you must be on the bearing-line (see Fig. 23).

When you have completed these two methods of resection you may, if you like, do the exercise again by plotting the magnetic bearings. From your true north line on the map, draw a line cutting it at an angle of 15° to the west; this will be the magnetic north for use with your own particular compass. From the tree and the church draw magnetic north lines parallel to this one, and plot the *magnetic* bearings with your

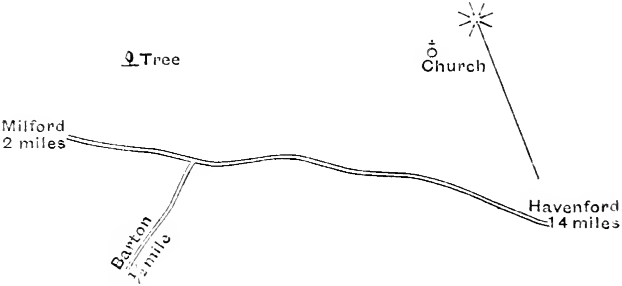


FIG. 23.

protractor. If you work accurately, the result must be the same (see Fig. 24).

We will now take an example of "intersection." Intersection is used for determining the range of distant objects from a certain spot, and also to enable distant objects to be put in, accurately, on a military sketch or on the enlargement of a map. Suppose that you are standing at the tree, and you want to know the range in yards to the church, and that there is a stream running between the tree and the church which prevents you from pacing the distance, proceed as follows. You will be able to judge roughly with the eye whether the range is a long one or a short one, and as you will have to plot the bearings on a blank piece of paper, or, for preference, on the squared paper of your Field Message Book, a scale will be necessary. You judge

FIG. 24.

the distance very roughly and decide that a scale of 1 inch to 100 yards will suit your purpose. You then make a scale on a blank page of your book as follows :

The sides of the squares in a Field Message Book are

FIG. 25.

$\frac{1}{4}$ of an inch. Then from your tree you have to decide on a *base-line* from each end of which you are going to take bearings on to the church. You have to decide in which direction to take the base in order to give you an angle as near to a right-angle as possible, for lines which intersect at right-angles have the sharpest and therefore the most accurate point of intersection. You decide on the direction and walk away from the tree, pacing the yards. You pace, say, 300 yards, and decide that this will give you a suitable base both in length and direction.

Mark the end of your base by sticking your cane

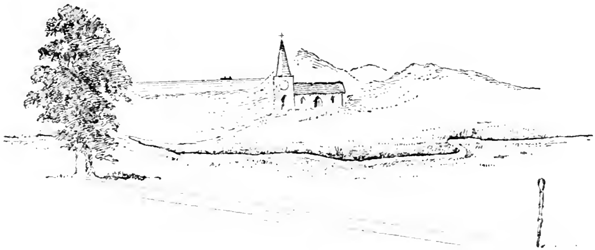


FIG. 26.

into the ground, or by some such means, and then, at the bottom of your page, draw a line 3 inches long to represent your base. Then with your compass take the bearing *along the base* to the tree. You find it to be 26° (magnetic). Then take your protractor and place the centre of it on the end of the base (on the paper) on which you are standing, and turn the protractor round until the base-line, or a continuation of

it, protrudes beyond the protractor at the 26th division. Then by drawing a line from the end of the base along the edge of the protractor towards the left-hand top side of it you will get your magnetic north (see Fig. 27).

You then take the bearing on to the church from

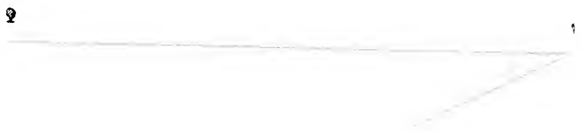


FIG. 27

this end of the base and you find it to be 55° (magnetic). Plot this from the end of your base on the paper (see Fig. 28).

FIG. 28.

You now know that the church with regard to the base is somewhere on this line. You can now take your cane away and walk back to the tree end of your base. You take the bearing of the church from the tree and find it to be 158° (magnetic). Plot this from

the other end of the base on the paper. You know the church must be in this line, and that it must be where this bearing-line cuts the one from the other end of the base (see Fig. 29).

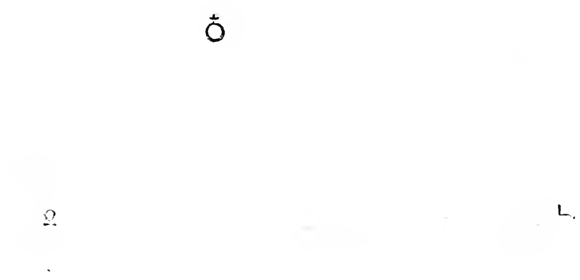


FIG. 29.

All you have to do now is to measure the line from the tree to the church by means of your scale; you find it to be 148 yards from the tree to the church.

You can now refer to the relationship of the church to the tree as, "Church, bearing from the tree 143° (true), 148 yards."

The greater the distance of the object of which you wish to find the range the longer your base-line will have to be.

You can also add data to your 1-inch map by using this method. Supposing, since the map was made, a house has been built and you wish to put it in, exactly, on your map. Select a base-line between two prominent objects marked on the map and proceed in the same manner, taking the bearing of the house from each end

of the base-line, and plot the true bearing from each of the prominent objects on the map. You will see that you can get the bearing and length of the base-line from your map, so the ends of the base-line need not be visible to each other, but the house must, of course, be visible from each. In this case the length of the base, or its bearing, need not be known, as they are fixed on the map, nor is there necessity to join up the ends of the base.

When using a map for resection or for any purpose which entails the plotting, on the map, of bearings taken on the ground with a compass, always convert your magnetic bearings into true ones and plot the true. When, however, plotting magnetic bearings on to a blank paper there is no necessity to do this; the magnetic bearings may be plotted straight away. The reason is obvious. To plot bearings, taken by compass, on to a small-scale map, is to run the risk of a slight error in drawing the magnetic north line (called the magnetic meridian) applicable to the particular compass used—an error which the use of the finest pointed pencil and the most careful working may incur; while, when working on blank paper, there is no necessity to transmute the bearings from the magnetic to the true, since the change in this case is a matter of calculation alone, there is no room for error to arise, and the result in each case is exactly the same.

Both in resection and intersection angles of less than 30° or greater than 150° are to be avoided, as their points of intersection are not definite enough for reasonable accuracy.

These examples, of course, do not by any means exhaust the ways in which bearings can be used; but, having mastered them, the student will easily be able

to apply his knowledge and to make bearings his useful servants in any cases which the situation of the moment may bring forth and his own ingenuity direct.

Problems

(1) (See page 18.)
(2) (See page 25.)
(3) (See page 25.)
(4) (See page 26.)
(5) (See page 26.)
(6) You take a bearing with your compass and find it to be 71°. You plot the true bearing on the map and find it to be 84°. What is the variation of your compass?
(7) Using Diagram IV as a map, you go out on to the actual ground and take the bearing from the church of the most southerly tree; your compass gives you a bearing of $91\frac{1}{2}$°. What is the variation of your compass?
(8) Two prominent objects on the ground are 380 yards apart on a true east-and-west line. You take bearings on to them from the same spot. The bearing to the westerly one is 317°, and to the other 54° (magnetic). The variation of your compass is 13° west. How far in yards are you from the most easterly object?
(9) If, in finding bearings on a map, you draw no line that does not protrude at least $\frac{1}{2}$ an inch beyond the edge of the protractor when the protractor is applied to it, what is the length of the longest line you need draw, and what will be the bearing

or bearings which will entail its use? (This applies to the Rectangular Protractor, 6 inches, wood "A" Mark II.)

(10) You wish to ascertain the range of a distant village in yards, taking your bearings on to the spire of the village church. You fix your base, making it 500 yards long, the centre of the base being the spot from which you wish to measure the range. The bearing of your base you find to be 255°. The bearing on to the spire from the west end of your base is 357°, and from the east end 326°. What is the range of the village?

(11) You know of a house, a church, and a windmill. The church and the house are both visible from the windmill, but the church is not visible from the house. You have no map and wish to find the distance and bearing of the house from the church. You find the following: Church to windmill, 125°—530 yards; house to windmill, 81°—256 yards. What are the distance and bearing of the house from the church?

(12) A true bearing is 338°, the magnetic bearing is 5°. What is the variation of the compass?

Answers to Problems

(1) The most north-westerly tree.
(2) 10° west.
(3) 20° east.
(4) 15° east.
(5) 25° west.
(6) 13° east.
(7) 9° west.
(8) 215 yards.
(9) 4·05 inches. 33°. 147°. 213°. 327°.
(10) 912 yards.
(11) 152°, 490 yards.
(12) 27° west.

APPENDIX

Scales of Yards

" The word SCALE is used to denote the proportion which a distance between any two points on a sketch or map bears to the horizontal distance between the same two points on the ground."—*Manual of Map Reading and Field Sketching*, 1912.

It is supposed that the student has become familiar with the elementary principles of map-reading and field-sketching and that he is now applying his knowledge. One of the most useful things with which he will have to deal will be scales of yards, and it will often be found not only useful but necessary to construct a scale of yards, for use on a map, from data supplied at the bottom of the map. For instance, take any 1-inch Ordnance Survey sheet of England and Wales, and the data at the bottom consists of a representative fraction, a scale of miles and furlongs, and the words, " 1 inch to 1 statute mile." You may find yourself working on this map, and, for military purposes, need to measure distances in yards, so you have to construct your own scale of yards for the purpose. This is always easy where the representative fraction is known. In the case of the English 1-inch maps, the representative fraction (R.F.) is $\frac{1}{63,360}$, or, 1 inch on the map represents 63,360 inches on the ground, 1 yard on the map represents 63,360 yards on the ground; in fact, a distance on the map is one sixty-three thousand three hundred and sixtieth times smaller than the distance in the country which it represents.

Now a convenient length of line for a scale drawn at the bottom of a map or sketch is anything between 4 and 6 inches long; so what you have to do is to find, from your data, a *round* number of yards, which will give you a line of this length. In other words, find the *exact* length of a line between 4 and 6 inches which will give you, on the particular scale used, a convenient round number of yards. The affair then resolves itself into a proportion sum.

63,360 yards on the ground is represented by 1 yard on the paper. Or 63,360 yards on the ground is represented by 36 inches on the paper.

You want to find a line about 6 inches long, so if you now divide by 6 you will get the number of *yards* represented by 6 inches.

10,560 yards on the ground are represented by 6 inches on the paper.

You have here got a definite relation between yards and inches, the thing to do now is to take the nearest convenient round number of yards in thousands and find by how many inches it is represented. If you take 11,000 yards, it is clear that you will be exceeding the 6 inches limit, so for the sake of convenience take 9,000 yards.

So if—

10,560 yards are represented by 6 inches

1 yard is ,, ,, $\frac{6}{10,560}$ inches

9,000 yards are ,, ,, $\frac{6}{10,560} \times 9,000$ inches.

Work out this fraction and you will find that 9,000 yards are represented by 5·11 inches. (It is unnecessary to carry the calculation beyond the second decimal.)

The next thing you do is to draw a line 5·11 inches long on the map or sketch that you are using. To do this an explanation of the diagonal scale on the service protractor is necessary. On the reverse side of the protractor you will see this:

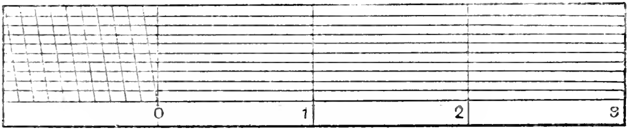


FIG. 30.

This is a scale for enabling you to draw a line to the hundredth part of an inch, also to check distances with the same minuteness and accuracy. Suppose you wish to measure off a distance of 2·47 inches, you place one point of your dividers on the point where the vertical line marked 2 cuts the lowest horizontal line above that figure. Place the other point of the dividers where fourth division line on the left side of the o meets this horizontal line. As there are 10 divisions in the inch on the left of the o, this will give you a length of 2·4 inches. Now count upwards for seven horizontal lines, and where the fourth diagonal line cuts the seventh horizontal line, put the point of the dividers. Now from this point open out the dividers until the other point rests where the seventh horizontal line upwards cuts the vertical line from 2. This distance is 2·47 inches (follow red part of diagram). You are now able on any straight line to mark off a length of 2·47 inches.

Now draw your line 5·11 inches long, by marking off a distance of 4 inches on a straight line, and then adding 1·11 inches to it—by starting from the 1 on the sliding scale and counting one division along and one up.

Divide up this line into nine equal parts. The following method is quite simple. From one end of the line to be divided, draw a line of suitable length at an angle of about 45°. From this line measure off any nine equal parts with the dividers, or by ticking off nine equal lengths from the edge of a piece of paper. Join up the last division line with the end of the line to be divided, and through the eight

other divisions draw parallels to this end line, cutting the line to be divided.

FIG. 31.

Your line is now divided into nine equal parts. Rub out the lines drawn to achieve this end.

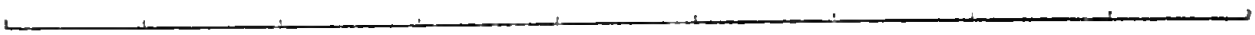


FIG. 32.

The next thing to do is to mark the divisions clearly, each representing 1,000 yards. Note that you count the first division from the left as 0, the left end of the scale as 1,000; and then from the 0 up to 8,000 on the right.

FIG. 33.

Then by very careful working and with the method described above, divide the division between the 0 and the 1,000 on the left into 10 equal parts.

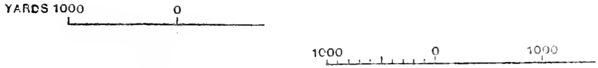


FIG. 34.

Each of these divisions will now equal 100 yards. So if you take a distance off your map with the dividers and find that, by putting one end of the dividers on the 0, the other end comes between the 4,000 and 5,000 divisions, you know the distance to be between 4,000 and 5,000 yards. Now place one end of the dividers on the division marked 4,000, the other end will give you the odd number of hundreds, as it will overlap the 0 division into the hundreds.

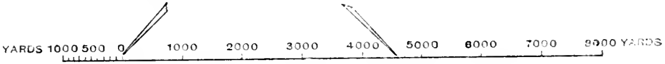


FIG. 35.

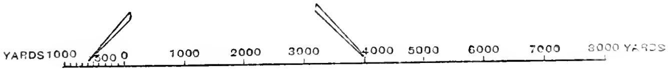


FIG. 36.

It will generally be found more convenient, if adding a scale of yards to a map in permanent use, to make the scale separately and then copy it on to the map.

You will find scales of yards on your protractor, equivalent to various scales of inches to the mile.

It is always more accurate to find, say, how many inches equal 9,000 yards, and to divide the line nine times, than it is to find how many inches equal 1,000 yards and increase the length by nine; the reason being that lengths become too minute beyond the second decimal place. We take ·56 of an inch to equal 1,000 yards on a 1-inch map; nine times ·56 is 5·04 inches. Now the nearest accurate length of line to represent 9,000 yards is 5·11 inches, the reason for the discrepancy being that the real length of line to represent 1,000 yards is ·5681818 inches, and though it is not necessary or hardly possible to carry the length of a line to thousandths of an inch—yet when this length of line of two decimal places is repeated, the error becomes greater at each repetition. So always remember in working, wherever possible, work from the greater to the less. In the above case working from the less to the greater you get an error of ·07 inches in 5·11 inches, or of 125 yards on the scale when measuring a distance of 9,000 yards.

This one example of scales of yards is given because "yards" is the unit of measure which is most in use in the British Army—ranges and judging of distance are always worked in yards.

Knowing the way to transmute a scale into inches representing yards, by means of a proportion sum, and the method of dividing up the line of required length into divisions representing round hundreds and thousands of yards, the student will be able to form a scale of yards from *any* representative fraction that he may be given, and very little practice should enable him to do so quickly without the aid of the book.

Examination Paper

(*a*) Imagine that you are on a plain and that you march on a bearing of 27° for 350 yards from a given spot. You then march on a bearing of 193° for 700 yards. From the

last point arrived at you march away in a certain direction, and from the last point at which you arrive you take the bearing of your original starting-point and find it to be $280\frac{1}{2}°$, and you find the distance to be 1,180 yards. How do you now stand as regards distance and bearing to (1) your first turning-point, and (2) your second turning-point?

(*b*) Plot the following to a scale of 1 inch to 100 yards.

B to A 195°	C to H 320°
C to A 270°	C to B 320°
D to A 350°	C to E 240°
E to A 30°	C to D 220°
F to A 90°	E to F 350°
G to A 160°	F to G 20°
H to A 180°	Distance B to A 300 yards.

And find: (1) distance and bearing G to C, (2) distance and bearing E to H.

(*c*) Imagine yourself and another to be making a field sketch of a piece of country, and that you have no map. You wish to find the bearing of a certain church from a certain tree. The church is invisible from the tree, but a third object, a windmill, is visible from both. You find the distance from the church to the tree to be 250 yards, and from the tree to the windmill to be 300 yards. From the windmill you take the bearing of the church and find it to be 220°, and of the tree and find it to be 270°. You each commence to plot upon these data, and each get a different result, one finding the bearing tree to church 107° and the other making it 153°. Which is correct? Give reasons for the discrepancy and state its origin.

(*d*) You are in a line of trench 1,600 yards long. For the time being the enemy is not in touch with you, but you wish to make a range-card without leaving the trench. From the west end of your trench you find the bearing of the trench-line to be 71°. You then take bearings from the west end of the line and find the

following: Village church 94°, farm 115°, wood 120°, pine tree 92°, cross-roads 110°, château 149°.

From the east end of the line you find the following: Village church 175°, wood 188°, farm 172°, pine tree 214°, château 212°, cross-roads 205°.

The particular section of trench from which you wish to know the ranges is 500 yards from the west end of the line. Give the range of each object.

(*e*) Draw a complete map from the data supplied in question (*d*), with the following added: Spinney from east end of line 123°, from west end 84°. Road running direct from spinney to village and from village to cross-roads, thence to château. Road running from farm to cross-roads and from cross-roads through the line of defence, cutting it at a distance of 280 yards from the west end. A footpath runs from the village to the pine tree and from the pine tree to the château.

(*f*) Having your range-card ready, you see a column of enemy troops leave the village and proceed along the VILLAGE—CHATEAU road. At what range would you open fire when the column is half-way between the village and the cross-roads?

(*g*) At a certain point on the line of defence the pine tree and the farm are in the same line of vision. How far is this point from the east end of the defence line? What is the bearing from the west end of the line of trench to the spot where this line of vision cuts the VILLAGE—CHATEAU road?

(*h*) Suddenly from behind the wood a company of the enemy emerges and is seen to be making for the cross-roads. When the company is half-way between these two points it disappears into some dead ground and does not reappear. The artillery in rear knows the exact position of the defence line. What information would you send back to the artillery officer, supposing you had observed this from the west end of the line? The variation of your compass is 16° west.

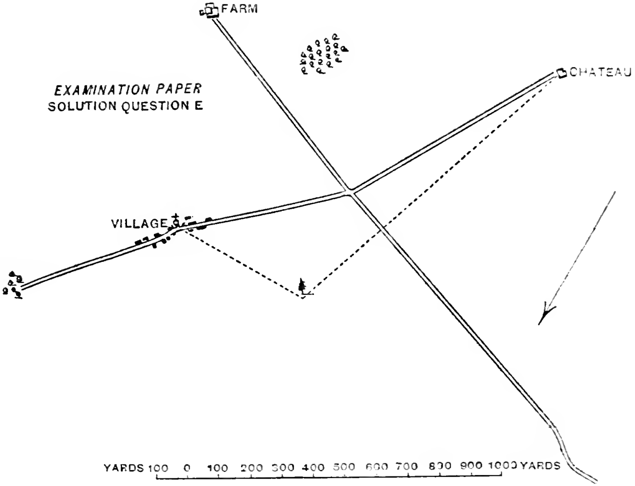
(*i*) At what range would you open fire on troops moving

along the PINE TREE—CHÂTEAU footpath as they were crossing over the road?

(*k*) From the west end of the line you notice that the enemy is placing a battery in a certain position. You take a bearing from the west end of the trench and find it to be 125°, and from the east end and find it to be 201°. The next day the battery is moved and you find its bearings in the new position to be from the east end 218° and from the west end 143°. How far has it moved, and what is now its bearing from the point in the defence line from which you measured the original ranges?

EXAMINATION PAPER (SOLUTIONS)

(*a*) (1) 298°, 1,130 yards. (2) 263°, 1,170 yards.
(*b*) (1) 125°, 520 yards. (2) 14°, 680 yards.
(*c*) Either may be correct. Each bearing is taken from a distance 250 yards from the church, but the distance WINDMILL—CHURCH should have been ascertained before plotting.
(*d*) Church 1,120 yards, farm 1,580 yards, cross-roads 830 yards, pine tree 690 yards, château 1,140 yards, wood 1,290 yards.
(*e*) (See map on page 52.)
(*f*) 950 yards.
(*g*) (1) 680 yards. (2) 102°.
(*h*) "Company of enemy halted in dead ground 100° 1,350 yards from east end of our line, between wood and cross-roads."
(*i*) 650 or 700 yards.
(*k*) 480 yards, 176°.



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